"Light, Waves and Interference" - A Teacher's Workshop

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Jet Propulsion Laboratory
California Institute of Technology
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Slinky® Waves

Background

Simple, transverse waves travel through many different media. Examples include water waves, S-type earthquake waves, and all electromagnetic waves, from radio signals through light to x-rays and gamma rays. Similarly, longitudinal waves are commonly found, from P-type earthquake waves to the sound waves we detect with our ears. These two types of waves can be easily demonstrated with a Slinky® or equivalent coiled spring toy.

Transverse and longitudinal waves can both be observed as traveling waves and as standing waves. A traveling wave moves along the medium, carrying energy from the origin outward. A standing wave is confined, and must have a precise relationship between its characteristic size (called its wavelength) and the size of its confinement. Specifically, a standing wave must have an integral number of ½-wavelengths in the confinement zone. It can be considered a collection of traveling waves that, together, sum up so that there are nodes (positions of no wave motion) at the ends of the confinement zone, possibly with additional nodes between the ends.

This activity demonstrates traveling and standing waves and transverse and longitudinal waves.

Materials

- Coiled spring toy (Slinky® or equivalent)
- Fixed attachment point for the spring

Set-up

Attach one end of the spring to a file cabinet, book shelf, or other solid, fixed piece of furniture. The end should not be free to move when attached, and should not come loose when the spring is shaken violently. A student can hold the "fixed" end, but must hold it tightly and in one position.

Procedure

Extend the spring across the room. Once it has settled, generate a traveling transverse wave by using a finger to make a quick pull & release in a vertical orientation. Try this several times, observing the reflection of the wave after it reaches the fixed end of the spring.

When the spring is again quiet, generate a traveling longitudinal wave by pulling a few coils towards yourself and then releasing them. A compression/rarefaction combination will travel along the spring, and may reflect if the initial wave is strong enough. Repeat this several times. Is there a difference in wave speed for transverse and longitudinal waves? (The answer for P- and S- earthquake waves is yes.)

Now generate a standing wave. Using your arm, move the end of the spring up and down at a slow rate. Find the frequency necessary to get a single U-shape (transforming to an inverted U) of the spring between the moving end and the fixed end. When found, only small amplitude arm motions are necessary to maintain this shape, which has a wavelength that is <u>twice</u> the length of the extended spring. This can be interpreted as the wave and its reflection exactly canceling out their respective motions at the fixed end and at your hand. Points where there is zero motion are called nodes.

Increase your arm-waving frequency. The spring's shape is disrupted, and waves and reflections interfere with each other and make chaotic spring motion until the correct frequency (twice the first one) is found. This new frequency permits two U/inverted U pairs to form in the spring with one node in between. Now one wavelength is equal to the distance from your hand to the fixed end. Try higher frequency arm-waving to put 1.5 wavelengths (three U's, separated by two nodes + the two ends) and 2 wavelengths (four U's, separated by 3 nodes + the two ends) along the spring.

How are wavelength and frequency related?

<u>Extension</u>

The standing waves in the demonstration were made by shaking the spring vertically, yielding waves with vertical polarization. Similarly, waves can be made by shaking the spring horizontally (harder for students to see from the seats).

If the spring is shaken with a circular arm motion (easier than maintaining pure vertical motion), the U-shape also follows a circular path (like a jump rope). This is circular polarization. But if one looks along the length of the spring and observes only vertical or horizontal motion (a long, thin rectangle cut into cardboard will make this easier to see), one can observe that the circular motion resolves into an equal combination of vertical and horizontal polarizations. These are analogs to polarization observed in electromagnetic waves that have practical applications in daily life and in spaceflight.

<u>Benchmarks and Standards</u>

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

Standard: 12 *Understands motion and the principles that explain it.*

Level I: Primary (Grades K-2) - Knows that things move in many different ways (e.g., straight line, zigzag, vibration, circular motion).

Level III: Middle School/Jr. High (Grades 6-8) - Knows that vibrations (e.g., sounds, earthquakes) move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source.

Standard: 15   *Understands the nature of scientific inquiry.*
Level I: Primary (Grades K-2) - Knows that learning can come from careful observations and simple experiments.

Level II: Upper Elementary (Grades 3-5) - Plans and conducts simple investigations (e.g., makes systematic observations, conducts simple experiments to answer questions).